

Glucose Monitoring and Hypoglycemia Awareness in Saudi Arabian Patients with Type 2 Diabetes: A Cross-sectional Study

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ABSTRACT

Type 2 Diabetes Mellitus represents a global epidemic with overall 17.7% prevalence rate in Saudi Arabia. Many patients need Continuous glucose monitoring to avoid fluctuations in blood glucose level with hypoglycemia threatened the life of many diabetics especially elderly. This study investigates the knowledge of patients with T2DM regarding recognition of hypoglycemia and their experiences with glucose monitoring systems. A questionnaires based cross-sectional study was conducted among T2DM Saudi patients who used Continuous glucose monitoring devices to adjust their blood glucose level and medication dosage. The Questionnaire covers three domains which are: demographics, device satisfaction, and awareness of low blood sugar events. Our study revealed that the demographic distribution of our participants was 59% female, 41% male with average age of 44 years. The participants gave mixed responses regarding blood glucose monitoring devices where 31.5% of responders found them convenient, while 31.1% were indifferent and a significant portion; 37.7% of them disagreed with their value. Worryingly, only 59.4% of participants consistently monitored their blood sugar during hypoglycaemia, highlighting a potential risk of neglecting this vital practice. Our research identified a significant knowledge gap among T2DM patients in Saudi Arabia regarding hypoglycemia awareness and management. Educational and technological solutions are crucial to empower patients and improve their overall health outcomes.

Keywords: Type 2 Diabetes Mellites, Hypoglycaemia, Glucose Monitoring Devices, Prevalence, Management, Techniques

INTRODUCTION

Hyperglycemia, a key manifestation of diabetes mellitus (DM), may impact the body's energy utilization efficiency with imbalance in the body's metabolism of fats, proteins, carbs, and other nutrients. Insufficient insulin secretion and peripheral insulin resistance are two the main etiological factors contribute to the pathogenesis^{1,2}. Although hypoglycemia is defined as serum blood glucose level below 70 mg/dl, its symptoms do not show up until blood glucose levels are below 55 mg/dl³; severe hypoglycemia, which can be presented by coma that if untreated promptly can progress to permanent neuronal damage and eventually death⁴. According to the world health organization (WHO), Saudi Arabia has the seventh-highest prevalence of DM worldwide, and the second-highest in the Middle East. Over seven million individuals in the country are estimated to have diabetes, and over three million are pre-diabetes⁵.

Diabetics need proper long-term control of blood glucose level to avoid both acute as well as chronic complications either macro or microvascular⁶. A Continuous Glucose Monitoring (CGM) system is an effective tool that enable diabetics to monitor their blood glucose levels continuously⁷. These devices typically use a compact flex sensor that is placed beneath the skin. It measures the glucose level in the interstitial fluid at regular intervals. The sensor can then be wirelessly connected to a monitor to collect data about the changes in glucose levels over time⁸.

Raising awareness of T2DM patients about glucose monitoring and hypoglycemia is critical to the condition's management in Saudi Arabia⁹. Self-monitoring of blood glucose (SMBG) has been highly recommended for individuals with DM and is an essential part of diabetic care. For individuals with T2DM, regular and precise blood

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glucose monitoring, physical activity, and insulin-to-carbohydrate ratio adjustment are essential components of diabetic care¹⁰.

Continuous glucose monitoring (CGM) is a valuable tool for managing T2DM. Studies have shown it can improve patient outcomes^{8,10}. However, its effective use requires proper education. Patients need to understand how CGM works and how to use the data to regulate their blood sugar levels and avoid emergencies like hypoglycaemia.

In Saudi Arabia, the increasing prevalence of T2DM in young adults and children presents a complex challenge. Lifestyle factors and lack of awareness are likely contributing causes¹¹. Educational programs within the school system could be a solution, but policymakers need evidence-based data to support such initiatives. Therefore, this study aimed to assess the knowledge of T2DM patients regarding hypoglycaemia and their experiences with glucose monitoring devices, specifically focusing on how well they understand how to use them.

MATERIALS AND METHODS

Study Design: A cross-sectional study to assess the knowledge of T2DM Saudi patients about hypoglycemia as a complication of DM and to evaluate their experience with glucose monitoring devices was conducted, using a validated self-reporting questionnaire created on Google Forms, which was dispersed randomly through all social media platforms. The study protocol was approved by the Institutional Review Board of Fakeeh College of Medical Sciences, Jeddah (Approval no. 207/IRB/2021) as per the ethical standards.

Researchers used a questionnaire to collect data in two parts. The first part gathered basic demographic data like age, gender, and education. The second part focused on experiences with glucose monitoring devices. A validated questionnaire called the Glucose Monitoring Experience Questionnaire (GME-Q) (link: XX) was used to assess satisfaction with these devices in terms of ease of use, burden on daily life, and effectiveness. Another validated questionnaire, the Hypoglycaemia Awareness Questionnaire (HypoA-Q) (link: XX), measured how well participants could recognize low blood sugar events. In total, the questionnaires collected data on demographics, device satisfaction, and awareness of hypoglycaemia.

Data were collected in Microsoft Excel and analyzed using IBM SPSS Statistics version 23. The data were summarized using descriptive statistics, whereby categorical variables were shown as frequencies and percentages, and numerical variables as means and standard deviations. Multiple logistic regression analysis and other inferential statistical techniques were employed to find plausible factors influencing effective SMBG. The outcomes were presented as 95% confidence intervals (CIs) around odds ratios (ORs). A statistically significant p-value was defined as one that was less than 0.05.

Inclusion criteria: Inclusion criteria included all adults, both genders, and aged 18 years and above that are nationals of the Kingdom of Saudi Arabia and previously diagnosed with T2DM.

Exclusion criteria: Participants who were not Saudi nationals, those who were under 18 years of age, and who did not diagnosed as T2DM patients.

Sample size: The target sample size of 390 based on calculations of self-monitoring blood glucose prevalence. The data sheet and results were exported to a Microsoft Excel spreadsheet which was cleaned up, according to the exclusion/inclusion criteria.

Statistical analysis: Data were fed to the computer using IBM SPSS software package version 24.0. Qualitative data were described using number and percent. Comparison between different groups regarding categorical variables was tested using Chi-square test. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

RESULTS

Our research included 390 participants, most respondents were females (58.7%), while males represented 41.3%. Most respondents were married (55.8%), had a bachelor's (57.6%), and 35.8% were students. Forty-five percent of health care providers were private doctors and their monitoring device was contour next at 51% (Table 1). The minimum age was 15 and the maximum was 68 years old with the mean age (43.64) (Table 2).

Table 1. Sociodemographic characteristics of the participants (n=390).

| Variables | Frequency | Percent (%) |
|------------------------------|-----------|-------------|
| Gender | | |
| Male | 161 | 41.3 |
| Female | 229 | *58.7 |
| Marital status | | |
| Single | 143 | 36.7 |
| Married | 218 | *55.8 |
| Divorced | 22 | 5.7 |
| Widowed | 7 | 1.8 |
| Educational level | | |
| Primary | 2 | 0.5 |
| Intermediate | 2 | 0.5 |
| High school | 81 | 21 |
| Diploma | 29 | 7.4 |
| Bachelor's | 225 | *57.6 |
| Postgraduate | 51 | 13 |
| Employment status | | |
| Employee | 85 | 21.8 |
| Student | 140 | *35.8 |
| Retired | 136 | 34.9 |
| Housewife/I do not work | 29 | 7.4 |
| Health care providers | | |
| Privet sector | 175 | *45 |
| Government sector | 133 | 34 |
| Both | 82 | 21 |
| Monitoring device | | |
| Contour next | 199 | *51 |
| One call sharp | 56 | 14.5 |
| One-touch | 135 | 34.5 |

*Indicates the highest percent

Table 2. Descriptive Statistics for Age

| N | Minimum | Maximum | Mean | Std. Deviation |
|-----|---------|---------|-------|----------------|
| 390 | 15.00 | 68.00 | 43.64 | 17.76 |

Regarding the percentage of participants' agreement with the current method of blood glucose monitoring, 31.5% strongly agreed (it is easy to do). The participants agreed that it is discreet (34.6%), reassures them (32.7%), helps them to keep blood glucose within target levels (29.3%), makes them feel anxious about their glucose levels (34.3%), and aids them to avoid high blood glucose (32.7%). On the other hand,

some of the participants disagreed on two items (37.7%), the first being consuming a lot of time and the second being enabling them to have an accurate snapshot of their glucose levels. The participants didn't express a clear opinion on various aspects of glucose monitoring as it is convenient (31.1%) disrupts their sleep (40.4%), lets them be as physically active as they like (45.8%), makes them feel like a robot or machine (48.1%), feel self-conscious about their appearance (47.1%), receive an excessive amount of information (36.2%), experience unfavorable reactions in others, such as staring or questioning excessively (46.7%), and makes them constantly checking their glucose levels (42.3%). Furthermore, the respondents did not express a strong opinion on whether glucose monitoring assists in preventing hypoglycemia during the day (40.6%), causes pain or discomfort (45.8%), helps them determine if their glucose levels are dropping or rising (48.1%), helps them avoid hypoglycemia while they are sleeping (47.2%), provides them with the confidence to adjust their treatment regimen (36.2%) and allows them to feel unrestricted in their daily lives (46.7%). Some of them (42.3%) neither agreed nor disagreed regarding the effectiveness of the current monitoring method for their needs (Table 3).

The highest mean ever recorded (is easy to do) was 3.43+1.86 and the lowest mean (helps me recognize in which way my glucose is

moving—falling or rising) was 2.30+0.38. The overall mean was level (2.83+0.36) (agree) (Table 4).

Some participants reported that they never experienced symptoms of low blood sugar when monitoring blood glucose levels (61.1%), never were able to determine if they were hypoglycemic based on how they felt (58.6%), and never checked their blood sugar if they felt it was low (59.4%). Some reported that individuals were unaware of their hypoglycemia until after it occurred (77.8%), they were less alert to the onset of their hypoglycemia compared to earlier (39.5%), they no longer experienced the symptoms they used to have when their blood sugar was low (38.4%), and they have become more conscious of their hypoglycemia in the past six months (28.5%) (Table 5).

DISCUSSION

Our research findings indicated that a substantial percentage, precisely 61.1%, of individuals diagnosed with type 2 diabetes in Saudi Arabia do not exhibit discernible symptoms when experiencing a decrease in their blood glucose levels. The mentioned percentage is significantly higher than that reported by Chan et al., (2010)¹² in the Asia-Pacific region (35.8%) and the combined (including both partial and absent awareness) reported by Hepburn et al., (1993)¹³ (14%) among patients

Table 3. Frequency and percent of participant agreement with the current method of monitoring (n= 390)

| Item | Strongly agree | | Agree | | Neither agree/nor disagree | | Disagree | | Strongly disagree | |
|--|----------------|-------|-------|-------|----------------------------|-------|----------|-------|-------------------|------|
| | F | % | F | % | F | % | F | % | F | % |
| Is easy to do | 123 | *31.5 | 94 | 24.1 | 104 | 26.8 | 40 | 10.2 | 29 | 7.4 |
| Takes a lot of time | 18 | 4.7 | 30 | 7.6 | 125 | 32.1 | 147 | *37.7 | 70 | 17.9 |
| Is Convenient | 88 | 22.6 | 114 | 29.3 | 121 | *31.1 | 26 | 6.6 | 41 | 10.4 |
| Is discreet | 88 | 22.4 | 135 | *34.6 | 113 | 29.0 | 22 | 5.6 | 32 | 8.4 |
| Disrupts my sleep | 18 | 4.7 | 44 | 11.3 | 158 | *40.4 | 103 | 26.4 | 66 | 17.0 |
| Let me be as physically active as I like | 55 | 14.0 | 66 | 16.8 | 179 | *45.8 | 55 | 14.0 | 37 | 9.4 |
| Reassures me | 84 | 21.5 | 128 | *32.7 | 124 | 31.8 | 29 | 7.5 | 25 | 6.5 |
| Makes me feel like a robot machine | 33 | 8.5 | 22 | 5.7 | 187 | *48.1 | 88 | 22.6 | 60 | 15.1 |
| Makes me feel uncomfortable about how my body looks. | 26 | 6.7 | 23 | 5.8 | 184 | *47.1 | 105 | 26.9 | 53 | 13.5 |
| Gives me too much information. | 64 | 16.2 | 112 | 28.6 | 141 | *36.2 | 45 | 11.4 | 30 | 7.6 |
| Causes other people to react negatively (e.g. to stare/ask intrusive questions). | 22 | 5.7 | 52 | 13.3 | 182 | *46.7 | 78 | 20.0 | 56 | 14.3 |
| Means I am constantly looking at my glucose levels. | 49 | 12.5 | 79 | 20.2 | 165 | *42.3 | 56 | 14.4 | 42 | 10.6 |
| Means I have an accurate snapshot of my glucose levels. | 18 | 4.7 | 30 | 7.6 | 125 | 32.08 | 147 | *37.7 | 70 | 17.9 |
| Helps me keep my glucose levels within the target | 88 | 22.6 | 115 | *29.3 | 121 | 31.13 | 26 | 6.6 | 41 | 10.4 |
| Makes me feel anxious about my glucose levels. | 88 | 22.4 | 135 | *34.6 | 113 | 29.0 | 22 | 5.6 | 33 | 8.4 |
| Helps me to avoid hypos during the day. | 18 | 4.7 | 44 | 11.3 | 159 | *40.6 | 103 | 26.4 | 66 | 17.0 |
| Causes me pain or discomfort. | 55 | 14.0 | 66 | 16.8 | 179 | *45.8 | 55 | 14.02 | 37 | 9.4 |
| Helps me to avoid high glucose | 84 | 21.5 | 128 | *32.7 | 124 | 31.8 | 30 | 7.5 | 25 | 6.5 |
| Helps me know in which direction my glucose is moving (falling/rising). | 33 | 8.5 | 22 | 5.7 | 188 | *48.1 | 88 | 22.6 | 59 | 15.1 |
| Helps me to avoid hypos when I am asleep. | 26 | 6.7 | 23 | 5.8 | 184 | *47.2 | 105 | 26.9 | 52 | 13.5 |
| Gives me the confidence to make changes in my treatment | 63 | 16.2 | 111 | 28.4 | 141 | *36.2 | 45 | 11.4 | 30 | 7.6 |
| Gives me freedom in my everyday life | 22 | 5.7 | 52 | 13.3 | 182 | *46.7 | 78 | 20.0 | 56 | 14.3 |
| Overall, my current method of monitoring suits me well. | 49 | 12.5 | 79 | 20.2 | 165 | *42.3 | 56 | 14.4 | 41 | 10.6 |

*Indicates the highest percent

Table 4. Mean and standard deviation of participant agreement for the current method of monitoring (n=390).

| Item | Mean | Std. | Agreement |
|---|------------------|------|----------------------------|
| Is easy to do | *3.43 | 1.86 | Agree |
| Takes a lot of time | 2.57 | 1.33 | Disagree |
| Is Convenient | 2.53 | 0.76 | Neither agree\nor disagree |
| Is discreet | 2.68 | 0.92 | Agree |
| Disrupts my sleep | 3.40 | 1.89 | Neither agree\nor disagree |
| Let me be as physically active as I like | 2.88 | 0.79 | Neither agree\nor disagree |
| Reassures me | 2.45 | 0.86 | Disagree |
| Makes me feel like a robot machine | 3.31 | 1.80 | Neither agree\nor disagree |
| Makes me feel uncomfortable about How my body looks. | 3.35 | 1.76 | Neither agree\nor disagree |
| Gives me too much information. | 2.66 | 0.92 | Neither agree\nor disagree |
| Causes other people to react negatively (e.g. to stare/ask intrusive questions) | 3.24 | 1.76 | Neither agree\nor disagree |
| Means I am constantly looking at my glucose levels. | 2.90 | 0.57 | Neither agree\nor disagree |
| Means I have an accurate snapshot of my glucose levels. | 2.58 | 0.46 | Disagree |
| Helps me keep my glucose levels within the target | 2.63 | 0.55 | Agree |
| Makes me feel anxious about my glucose levels. | 2.70 | 0.44 | Agree |
| Helps me to avoid hypos during the day. | 3.41 | 1.38 | Agree |
| Causes me pain or discomfort. | 2.62 | 0.85 | Neither agree\nor disagree |
| Helps me to avoid high glucose | 2.64 | 1.04 | Agree |
| Helps me know in which direction my glucose is moving (falling/rising). | 2.30 | 0.38 | Disagree |
| Helps me to avoid hypos when I am asleep. | 3.36 | 1.e4 | Neither agree\nor disagree |
| Gives me the confidence to make changes in my treatment | 2.66 | 0.99 | Neither agree\nor disagree |
| Gives me freedom in my everyday life. | 3.22 | 1.49 | Neither agree\nor disagree |
| Overall, my current method of monitoring suits me well. | 2.50 | 0.48 | Neither agree\nor disagree |
| Total Mean | 2.83±0.36 | | Agree |

*Indicates the highest Mean; Strongly Agree =4.20- 5.00; Agree = 3.40- 4.20; Neither agree\nor disagree = 2.60- 3.40; Disagree = 1.80- 2.60

Table 5. Frequency and percent of blood glucose monitoring and symptoms of hypoglycemia (n=390)

| Item | Never | | Rarely | | Sometimes | | Often | | Always | |
|--|-------|-------|--------|------|-----------|------|-------|------|--------|------|
| | F | % | F | % | F | % | F | % | F | % |
| I have symptoms when my blood glucose is low | 240 | *61.1 | 54 | 13.6 | 27 | 14.2 | 56 | 8.0 | 13 | 3.1 |
| I 'just know' when I am going hypo that I feel | 232 | *59.6 | 45 | 11.2 | 53 | 13.7 | 33 | 8.7 | 27 | 6.8 |
| I check my blood glucose level if I feel 'low' | 232 | *59.4 | 27 | 6.9 | 56 | 14.4 | 34 | 8.8 | 41 | 10.6 |
| Other people recognize I am hypo before I do | 303 | *77.8 | 34 | 8.6 | 36 | 9.3 | 10 | 2.5 | 7 | 1.9 |
| I am less aware of my hypos coming on than I used to be | 152 | *39.5 | 65 | 16.6 | 45 | 28.7 | 109 | 10.2 | 19 | 5.1 |
| I have lost the symptoms I used to have when my blood glucose was low | 149 | *38.4 | 79 | 20.1 | 118 | 30.2 | 37 | 9.4 | 7 | 1.9 |
| In the past 6 months, I have been more aware of my hypos coming on than I used to be | 111 | *28.5 | 37 | 9.5 | 124 | 31.7 | 92 | 23.4 | 26 | 6.6 |

*Indicates the highest percent

undergoing insulin treatment. The noticeable lack of awareness highlights a critical area for intervention, particularly in instructing patients on recognizing and controlling hypoglycemia.

Our analysis indicated that advanced age and the utilization of insulin were significant predictors of a lack of awareness regarding symptoms of hypoglycemia. The findings were consistent with prior global investigations carried out by Murata et al., (2004)¹⁴ and Unger (2012)¹⁵. Our investigation uncovered that in 77.8% of instances, individuals other than the patients could detect hypoglycemia before the patients themselves. That emphasizes a notable dependence on caregivers and underscores the significance of improving strategies for self-awareness.

Only 59.4% of our participants conscientiously monitor their blood glucose levels when they experience symptoms of hypoglycemia, ignoring the potential dangers of neglecting this practice. This issue is particularly concerning and aligns with the findings of Harris

(2001)¹⁶, who noted that patients who are not using insulin are not receiving regular monitoring. This finding underscores the importance of promoting regular monitoring of glucose levels as a key aspect of effectively managing diabetes autonomously.

Our research exhibited an urgent need for behavioral interventions that specifically target improving self-monitoring practices. Research conducted by Jones (1990)¹⁷ and Moreland et al., (2006)¹⁸ demonstrated that the implementation of behavioral and educational strategies can greatly increase the frequency of monitoring. This discovery is particularly significant for the specific group of individuals being studied.

The study participants displayed varied responses to their current monitoring methods, with 31.1% showing apathy towards the convenience of their devices. These findings indicated that it is possible to improve the device's user-friendliness and enhance patient training.

The studies by Yeoh et al., (2015)¹⁹ and Choudhary and Amiel (2018)²⁰ have shown the benefits of structured education and modern diabetes technologies in effectively managing hypoglycemia.

A significant portion of our participants exhibited a gradual decrease in their capacity to detect hypoglycemia over a specific period, with 39.5% indicating a diminished awareness compared to their previous state. This finding aligns with prior studies that suggest the decline in question becomes more evident as the length of time an individual has had diabetes increases^{21,22}. To improve patients' awareness of hypoglycemic events, it may be necessary to pursue further education and consider adopting advanced technologies.

Considering that a significant proportion of our research participants rely heavily on others to detect hypoglycemia and do not consistently monitor their condition, there is an immediate need for comprehensive educational programs. These programs should give equal importance to the technical aspects of glucose monitoring and the capability to comprehend and respond to glucose readings, as evidenced by the accomplishments documented by Gan et al., (2010)²³ and by Mohamed et al., (2019)²⁴.

This study has some strengths and limitations. This cross-sectional study provides a snapshot of hypoglycemia management among diabetics in Saudi Arabia, pinpointing a need for improvement. However, due to the cross-sectional design nature, it cannot determine if poor management caused the hypoglycemia or vice versa. Additionally, the study relies on self-reported data which can be susceptible to bias.

CONCLUSIONS

This study identified a critical need for improvement in hypoglycemia management and education among patients with T2DM in Saudi Arabia. Technological advancements and educational programs providing knowledge and awareness can empower these individuals, ultimately leading to a better quality of life and overall health.

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